

LIFE HISTORY STRATEGY OF *LEUCISCUS PYRENAICUS* (CYPRINIDAE) IN INTERMITTENT STREAMS OF THE GUADIANA BASIN (PORTUGAL)

by

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ABSTRACT. - The aim of the study was to examine the ecology of *Leuciscus pyrenaicus* in intermittent streams in the middle reaches of the Guadiana basin, in southern Portugal, and examine the life history strategies this species adopts to survive the harsh environment conditions. Differences in growth and reproductive biology in three tributaries (Xévoira, Caia and Degebe) were examined. *L. pyrenaicus* contributed up to 12% by number to the fish community, although each population was dominated by small individuals. Males up to five years of age and females up to seven years were caught. Females attained a greater size and age than males. The fastest growth rate was found in the Xévoira river, where this species dominated the community structure and its "preferred" habitat characteristics were evident, i.e., moderately flowing water and coarse substrate. Changes in the gonadosomatic index (GSI) for sexually mature males and females suggest that gonad maturation occurs from October to April, and the spawning period is between April and July. Females from the Xévoira river were more fecund and this was linked to the less harsh conditions found in this river. The species exhibits an r-selected life history strategy to survive the extreme environmental conditions in intermittent streams in the Guadiana basin.

RÉSUMÉ. - Écologie et stratégies de survie de *Leuciscus pyrenaicus* (Cyprinidae) dans les cours d'eau intermittents du bassin hydrographique du Guadiana (Portugal).

L'écologie de *Leuciscus pyrenaicus* a été analysée dans des cours d'eau intermittents de la région centrale du bassin hydrographique du Guadiana, au sud du Portugal, ainsi que les stratégies de survie adoptées par l'espèce lorsqu'elle est soumise à des conditions environnementales extrêmes. Des différences dans la croissance et la reproduction ont été constatées dans trois fleuves tributaires de ce bassin (Xévoira, Caia et Degebe). *L. pyrenaicus* représente 12% de la communauté piscicole, bien que chaque population soit essentiellement dominée par de petits individus. Les femelles sont plus grandes et plus âgées que les mâles, avec un maximum de sept ans, alors que les mâles ne dépassent pas cinq ans dans les échantillonnages étudiés. Le taux de croissance le plus élevé a été trouvé dans le fleuve Xévoira où cette espèce domine la communauté et où ses préférences pour un habitat avec un flux d'eau modéré et un substrat grossier sont les plus évidentes. Les changements de l'index gonadosomatique (IGS) chez les mâles et les femelles matures suggèrent que la maturation des gonades a lieu d'octobre à avril et la période de ponte entre avril et juillet. Les femelles provenant du fleuve Xévoira sont plus fécondes que dans les autres tributaires, probablement en raison des conditions moins austères rencontrées dans ce fleuve. L'espèce présente donc une stratégie de type r pour faire face aux conditions environnementales extrêmes des cours d'eau intermittents du bassin.

Key words. - Cyprinidae - *Leuciscus pyrenaicus* - Portugal - Guadiana basin - Intermittent streams - Drought - Age - Growth - Reproduction.

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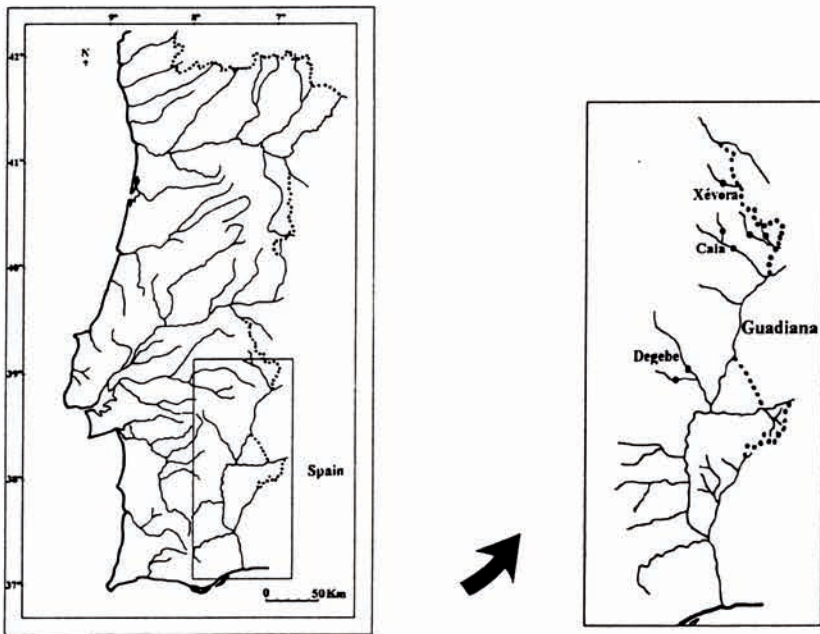


Fig. 1. - Sampling sites (•) on the three tributaries (Xévoa, Caia and Degebe rivers) in the middle reaches of the Guadiana basin.

The extreme Mediterranean climatic conditions experienced in the Iberian Peninsula cause strong seasonal fluctuations in the flow regime of rivers, especially in the south of Portugal (Collares-Pereira *et al.*, 1998). Many rivers that experience flooding in the winter and spring are dry or reduced to pools in the summer, exposing fish to extreme environmental conditions. However, despite the problems that the endemic fish species must face to survive in this harsh environment, no studies have been carried out to determine how they respond to the pressures imposed by the extremes in climate.

For example, one species, *Leuciscus pyrenaicus* Günther, 1868, is widely distributed in the Iberian Peninsula. It occurs in almost all catchments of southern Portugal (Almaça, 1965) and southern of Spain (Elvira, 1990). However, studies to date, both in Spanish (Lobón-Cerviá and Sostoa, 1987; Fernández-Delgado and Herrera, 1995; Encina and Granado-Lorencio, 1997) and Portuguese rivers (Magalhães, 1993a, 1993b; Gerales and Collares-Pereira, 1995; Coelho *et al.*, 1997), have mainly concentrated on its feeding habits.

The aim of this study was to examine the ecology of *L. pyrenaicus* in intermittent streams in the middle reaches of the Guadiana basin, a southern Portuguese catchment, and assess the strategies adopted to survive this harsh environment. This is extremely important for the conservation of such species as these rivers are coming under increasing pressure from water resources schemes.

Study area

The Guadiana river is a typical Mediterranean river. It flows 810 km from its headwaters in Spain to its mouth in Portugal, with 150 km of the main river and many

longer tributaries exclusively in Portugal, and 110 km of main river forming the border between the countries. The main rainfall period occurs between November and March, decreasing throughout the summer resulting in some tributaries of the river drying up or becoming a series of isolated pools.

Three tributaries (Xévoa, Caia and Degebe) in the middle reaches of the Guadiana river were selected for this study (Fig. 1). Although different stretches of each river were sampled (see Pires *et al.*, 1999, for details), data from each river were combined because low numbers of individuals were caught at some sites. The rivers are different in character and a combination of the three is considered representative of the different flow regimes (Pires *et al.*, 1999), i.e., more continuous flow (Xévoa) and isolated refuge pools in summer (Caia and Degebe). The Xévoa river is the most heterogeneous and has characteristics more typical of an upland stream with higher flow, lower water temperatures and higher water quality. Pool situations and no flow are more common in the Caia and Degebe rivers, which are more lowland rivers. The water temperature increases in these rivers with lower summer flows and this results in poorer water quality. Although all sites have some human pressure, the Xévoa and the Caia are more natural rivers than the Degebe, which has higher organic pollution (see Pires *et al.*, 1999, for details). The Degebe river is located in a more populated region with intense agriculture which increases the water pollution from run off. However, in general the Guadiana river basin has good water quality at all monitored sites.

MATERIALS AND METHODS

The fish populations were sampled approximately every three months from April 1995 to April 1997 using electric fishing (300 V, 3-4 A, DC). On each sampling occasion (April, July and October 1995, March, April, July and October 1996, February and April 1997), a 3-catch removal survey (Cowx, 1983) was carried out on a 50-m stretch of river, where each catch took approximately 30 min. Sampling in winter 1996 was delayed until March because of severe flooding.

All fish collected were identified, measured (total length nearest mm), weighed (nearest 0.1 g), sexed, and several scales were removed, mounted dry on microscope slides with a cover slip and examined to determine age and growth. At least five scales from each fish were examined independently by two persons. When agreement could not be reached a third opinion was sought. When no agreement could be reached on a fish age it was rejected from further analysis.

The total radius scale and distance from the focus to each annulus was measured using a microfiche reader ($\times 32$ magnification). The best fit relationship between scale radius and fish length was found along the dorso-anterior axis and this was used for back calculation of growth rates (Bagenal and Tesch, 1978; Francis, 1990). Back-calculations were made separately for males and females for each river, by substituting scale radius measurements to respective annuli in the appropriate regression equation. The relationships from each river were compared using analysis of covariance (ANCOVA). When significant differences were found between slopes or between elevations, a multiple comparison test was used to attribute the reason for the differences (Zar, 1984).

Both gonads were removed, weighed wet (nearest 0.01 g) and preserved in Gilson's fluid. Temporal patterns in gonad development were described using the gonadosomatic index ($GSI = [\text{gonad weight}/\text{total body weight}] \times 100$). Fecundity (F) was determi-

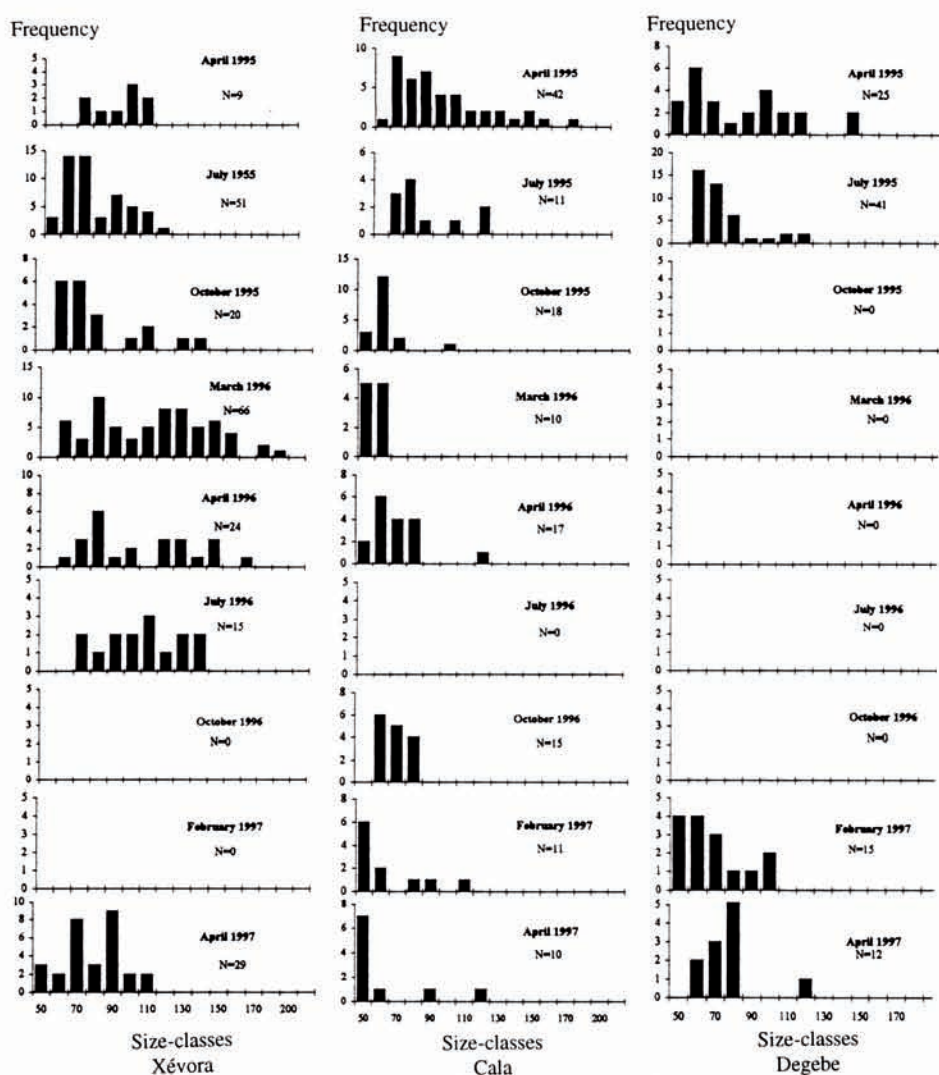


Fig. 2. - Size-classes distribution (class interval – 10 mm) of *Leuciscus pyrenaicus* caught on the three tributaries (Xévora, Caia and Degebe) in the middle reaches of the Guadiana basin.

Table I. - Fish community structure at the three rivers sampled.

Proportion of individuals by species (%)	Xévora	Caia	Degebe
<i>Leuciscus pyrenaicus</i>	16.3	12.0	5.0
" <i>Leuciscus alburnoides</i> complex"	40.5	43.3	51.9
<i>Chondrostoma</i> sp.	25.0	26.4	6.0
<i>Barbus</i> sp.	11.6	13.2	30.5
Others	6.6	5.1	6.6
Total number caught	4 350.0	2 719.0	2 482.0

ned gravimetrically (Bagenal and Braum, 1978) for mature females collected in April 1995, March and April 1996. The absolute fecundity was characterised by the number of ripening (yolky) eggs present in the gonads before spawning, and was related to total fish length. The diameter of 30 ripening ova was measured for each individual using an ocular micrometer.

RESULTS

Leuciscus pyrenaicus contributed up to 12% by number to the fish community structure (Table I; see Pires *et al.*, 1999, for details), although all populations in the three study rivers were dominated by small individuals (Fig. 2). The exceptions were March and April, at the beginning of the reproductive period, when larger individuals were found.

The best fit between the fish length (TL) and the scale radius (TSR) from each river was linear:

$$\text{Xévorá: TL} = 14.63 + 1.09 \text{ TSR} \quad (r^2 = 0.88; n = 161)$$

$$\text{Caia: TL} = 11.15 + 1.08 \text{ TSR} \quad (r^2 = 0.94; n = 114)$$

$$\text{Degebe: TL} = 14.30 + 1.04 \text{ TSR} \quad (r^2 = 0.93; n = 51)$$

Significant differences were found between the elevations on the three relationships (ANCOVA, $p < 0.05$), and the multiple comparison test (Tukey test) showed that the main differences were associated with the Xévorá and the Degebe rivers. Therefore, growth estimations were made separately for different sexes and rivers (Table II). Maximum back-calculated lengths were 181 mm TL (7 years) for females in Xévorá river and 149 mm TL (5 years) for males in Degebe river (Table II). Generally, females attained a greater size and age than males, and Degebe seemed to be the river where the species attained its fastest growth rate. However, significant differences in the back-calculated

Table II. - Back-calculated growth of *Leuciscus pyrenaicus* on the three tributaries of the Guadiana basin. Standard errors between brackets.

Age at capture	No. of fish	Length-at-age (mm)						
		I	II	III	IV	V	VI	VII
Xévorá	45							
Males		37 (0.93)	67 (1.78)	94 (1.88)	117 (1.67)	147 (1.01)		
Annual increment		30	27	23	30			
Females	101	53 (0.43)	74 (0.89)	100 (1.11)	123 (1.32)	147 (1.27)	155 (1.05)	181
Annual increment		21	26	23	24	8	26	
Caia								
Males	27	50 (0.80)	73 (1.73)	100 (2.75)	137 (3.31)			
Annual increment		23	27	37				
Females	68	46 (0.63)	65 (0.96)	88 (0.88)	112 (1.13)	131 (0.81)	180	
Annual increment		19	23	24	19	49		
Degebe								
Males	25	47 (0.90)	73 (1.57)	98 (1.95)	125	149		
Annual increment		26	25	27	24			
Females	9	60 (1.37)	80 (2.94)	101 (4.08)	123	154		
Annual increment		20	21	22	31			

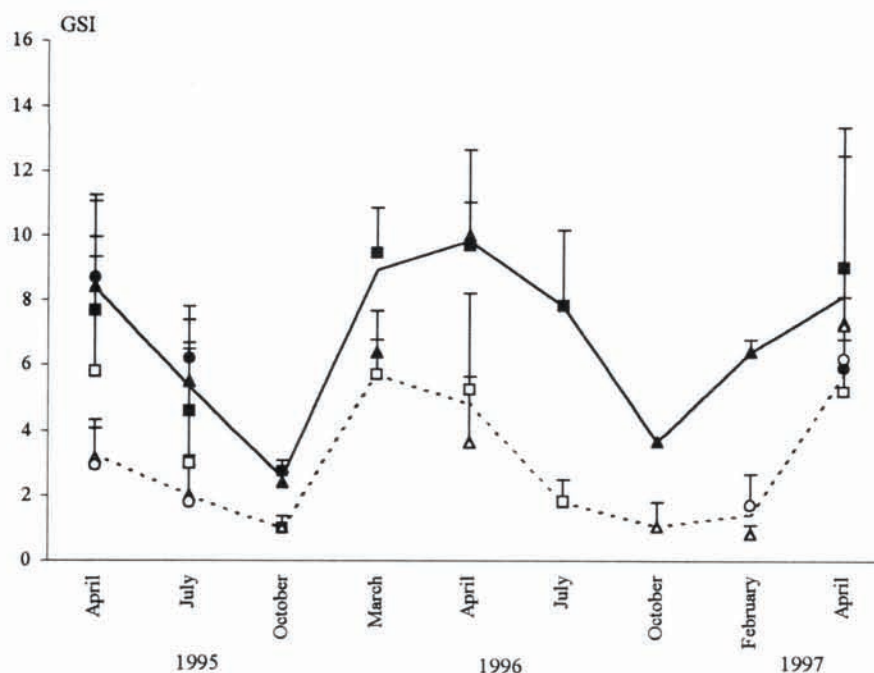


Fig. 3. - Seasonal changes in the gonadosomatic index (GSI) of *Leuciscus pyrenaicus* for the three rivers. Only the positive 95% confident limit were used to clarify the figure. — : GSI female (average); ---- : GSI males (average); ■ : GSI females (Xévoira); □ : GSI males (Xévoira); ▲ : GSI females (Caia); △ : GSI males (Caia); ● : GSI females (Degebe); ○ : GSI males (Degebe).

lengths for females and males were only found for the first and the second years of life (Mann-Whitney, $p < 0.01$). Significant differences were also found for the back-calculated lengths at age one and two (Kruskal-Wallis, $p < 0.01$) between rivers.

The logarithmic length (TL in mm) weight (TW in g) relationships were:

$$\text{Xévoira: } \log TW = -5.59 + 3.33 \log TL \quad (r^2 = 0.99; n = 161)$$

$$\text{Caia: } \log TW = -5.79 + 3.45 \log TL \quad (r^2 = 0.96; n = 114)$$

$$\text{Degebe: } \log TW = -5.43 + 3.26 \log TL \quad (r^2 = 0.98; n = 51)$$

Significant differences were also found between the three regressions (ANCOVA, $p < 0.05$) for the Xévoira and Caia rivers (Tukey test among elevations), which weighed more for the same length than the Degebe population.

Both male and female *L. pyrenaicus* first mature in their second year of life, although the majority of fish (especially females) are not mature until their third year. Changes in the gonadosomatic index (GSI) for sexually mature males and females (Fig. 3) suggest that gonad maturation occurs from October to April, and the spawning period is between April and July. However, the post-spawning quiescent period appears to be longer for males than for females (Fig. 3). In February 1997, males showed no evidence of maturation, and GSI only increased in March to reach a maximum in April. In females, GSI was consistently higher (Fig. 3) but evidence of gonad maturation was found as early as October to reach a maximum in April. The GSI values for both females and males were similar for the three rivers.

The ova size distribution (Fig. 4) showed a tendency for larger fish (< 130 mm TL) in all three rivers to have slightly larger eggs than smaller individuals. Although fecundity (F) was positively associated with fish size (TL):

$$\text{Xévorá: } \log F = -2.10 + 2.45 \log TL \quad (r^2 = 0.69; n = 69)$$

$$\text{Caia: } \log F = -2.51 + 2.57 \log TL \quad (r^2 = 0.49; n = 47)$$

$$\text{Degebe: } \log F = -3.03 + 2.83 \log TL \quad (r^2 = 0.72; n = 9)$$

Significant differences were found between the three rivers (ANCOVA, $p < 0.05$), related primarily to fish from the Degebe being more fecund for their size than the Xévorá and Caia rivers (Tukey test).

DISCUSSION

Mediterranean streams are characterized by a diverse range of physical conditions, including severe droughts and floods (Pires *et al.*, 1999). Temporal variation in stream flow is often considered to strongly affect the community structure of stream fishes (Roff, 1981) and affect reproductive effort/life-history patterns (Mann and Mills, 1985). In the present study, all three rivers were subjected to extreme variations in flow, especially during the summer months. The situation in the Caia and the Degebe was particularly severe, with many reaches drying up completely or being reduced to a few refuge pools maintained by groundwater seepage. During this period the fish were confined to small shallow pools, thereby increasing spatial competition (Cowx *et al.*, 1984; Cowx, 1990), and exposed to deteriorating water quality conditions as the drought progressed. To survive these harsh conditions, the fish species must exhibit some adaptation of their life-history patterns, and be tolerant of high temperatures and low dissolved oxygen levels.

Leuciscus pyrenaicus shows a number of responses to overcome the severe drought conditions it faces in the intermittent streams of the Guadiana. Furthermore, there appears to be subtle differences in the strategy adopted in the different studied rivers, which can be related to differences in the extreme environmental conditions encountered.

Generally, as found by Lobón-Cerviá and Sostoa (1987), and by Fernández-Delgado and Herrera (1995), females attained a greater size and age than males. The largest size and greatest age were achieved in the Xévorá population, where this species dominated the community structure and the river portrayed its "preferred" habitat characteristics, i.e., moderately flowing water and coarse substrate (Pires *et al.*, 1999). Furthermore, although all three rivers had an intermittent flow regime, drought conditions were particularly severe in the Caia and Degebe, where dessication of the river bed was particularly prevalent (Pires *et al.*, 1999).

The differences in growth rates between the rivers should be considered indicative of the variation in environmental conditions between rivers. In the Caia and Degebe, the rivers were dry or reduced to small pools for extended periods of time, when the fish would have been exposed to harsh environmental conditions and competition for limited food resources, conditions that probably suppressed growth and induced the false checking on the scales. Irrespective of the harsh conditions, *L. pyrenaicus* appears to grow faster in the Guadiana than in Spanish rivers (Lobón-Cerviá and Sostoa, 1987; Fernández-Delgado and Herrera, 1995), although the growth rate was similar to that found in the only other study on a Portuguese river, i.e., the Tejo (Geraldés and Collares-Pereira, 1995).

The rapid growth and early maturation of *L. pyrenaicus* in all three rivers is a life history tactic adopted by other species in intermittent streams (Aparicio and Sostoa,

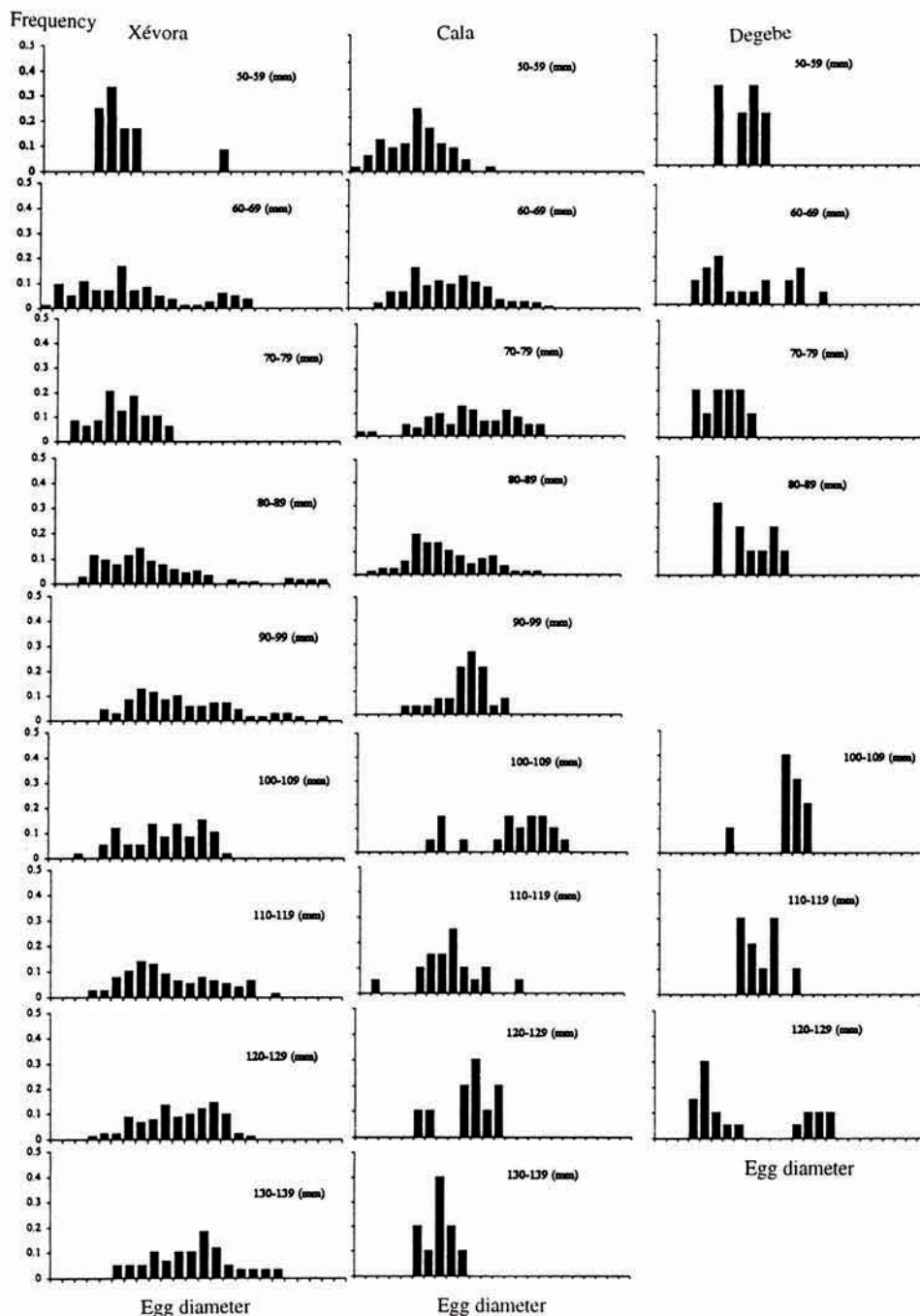


Fig. 4. - Egg distribution from different size-classes of *Leuciscus pyrenaicus* for the three rivers: Xévoira, Cala and Degebe.

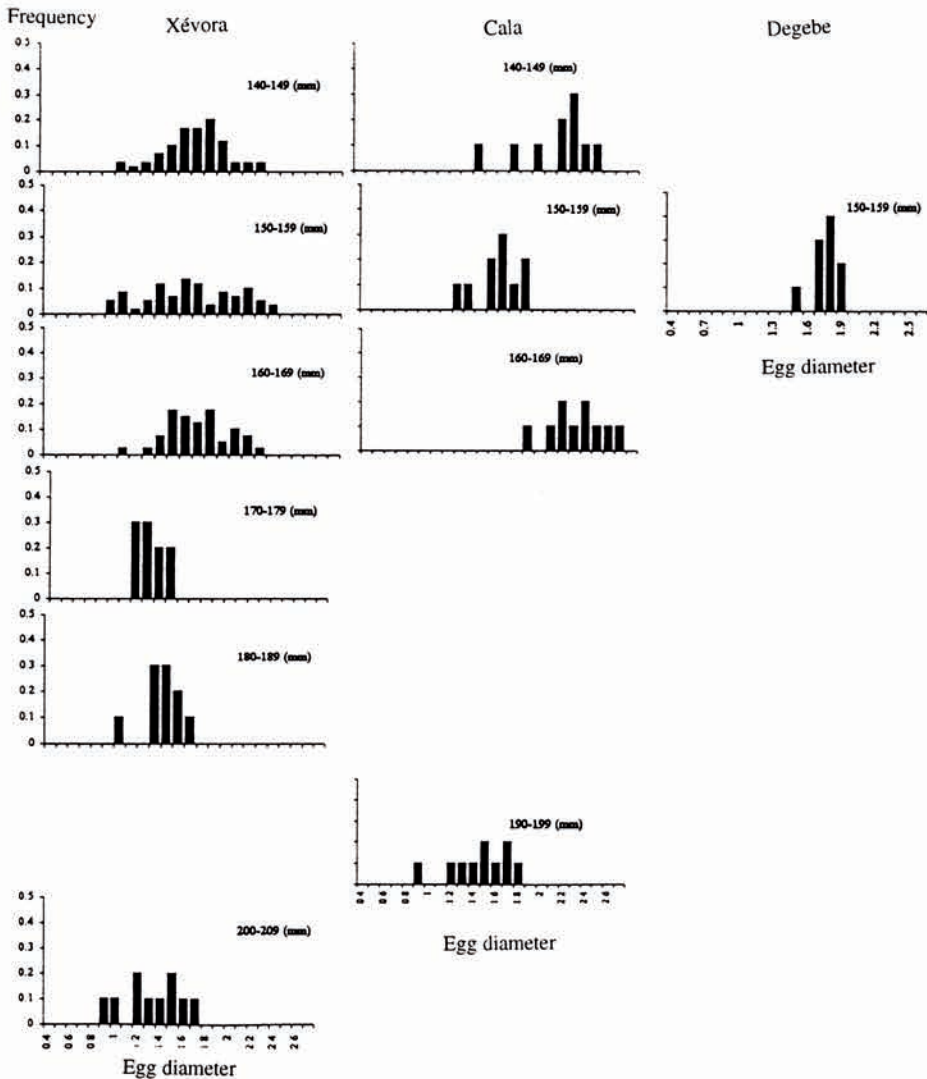


Fig. 4. - Continued.

1998). The species achieves sexual maturity at an early age to increase the reproductive investment in these stressed populations and ensure the maintenance of the population size. This tactic maximises reproductive output, and is a classic element in r-related life history strategies exhibited in stressful environments (Cowx, 1990; Wootton, 1993).

Unfortunately, because of the frequency of sampling in the present study, the precise timing and mechanism of spawning are not known. However, Fernández-Delgado and Herrera (1995) considered *L. pyrenaicus* is a multiple spawner that releases batches of eggs between April/May and July, with at least two batches of eggs per female. Such a tactic would explain the seasonal cycle in gonadosomatic index and considerable variabil-

ity in size of yolky eggs found prior to spawning during this study. Multiple spawning has indubitable advantages in fluctuating environments. Progeny are not risked in just one reproductive event where a climate catastrophe (spring flood or early summer drought) could preclude recruitment in a particular year. The mechanism also increases individual fecundity and avoids the trade-off between volume of body cavity and fecundity (Nikolsky, 1963). As fecundity increases with fish size, it becomes more profitable to increase the number of batches than the number of eggs per batch.

The intensity of the drought conditions exhibited between the studied rivers could explain the variability in fecundity observed. Lower fecundity was found in fish from the Xévoa where a more continuous flow regime was experienced. This provided a more stable environment for the resident population (Pires *et al.*, unpubl. data), which was manifest in reproductive output. No explanation is available for the variation in fecundity between years, although it is possible that the extremely wet winter of 1995 provided better food resources for the fish and they produced more (larger) eggs for their size. This would be a typical response of an r-selected species to maximise its reproductive output during favourable conditions (Cowx, 1990; Wootton 1993).

A further element is related to the migratory behaviour observed. The increased contribution of larger fish, especially females, prior to the spawning season suggests the fish migrate upstream, presumably from the larger rivers downstream which have permanent flow regimes, at this time to spawn. Following spawning the larger mature fish presumably return to the more stable lower reaches. This tactic will enhance the survival of the larger, older fish which are likely to be more vulnerable to poor water quality conditions, especially low dissolved oxygen (Wootton 1990), in the refuge pools. Such a tactic has been recognised throughout the Guadiana basin, whereby the rivers which dry during the summer are rapidly recolonised as soon as suitable flow conditions are reestablished during the winter (Collares-Pereira *et al.*, 1999).

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